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(54) **APPARATUS FOR THE PRETREATMENT AND SUBSEQUENT CONVEYING, PLASTIFICATION, OR AGGLOMERATION OF PLASTICS**

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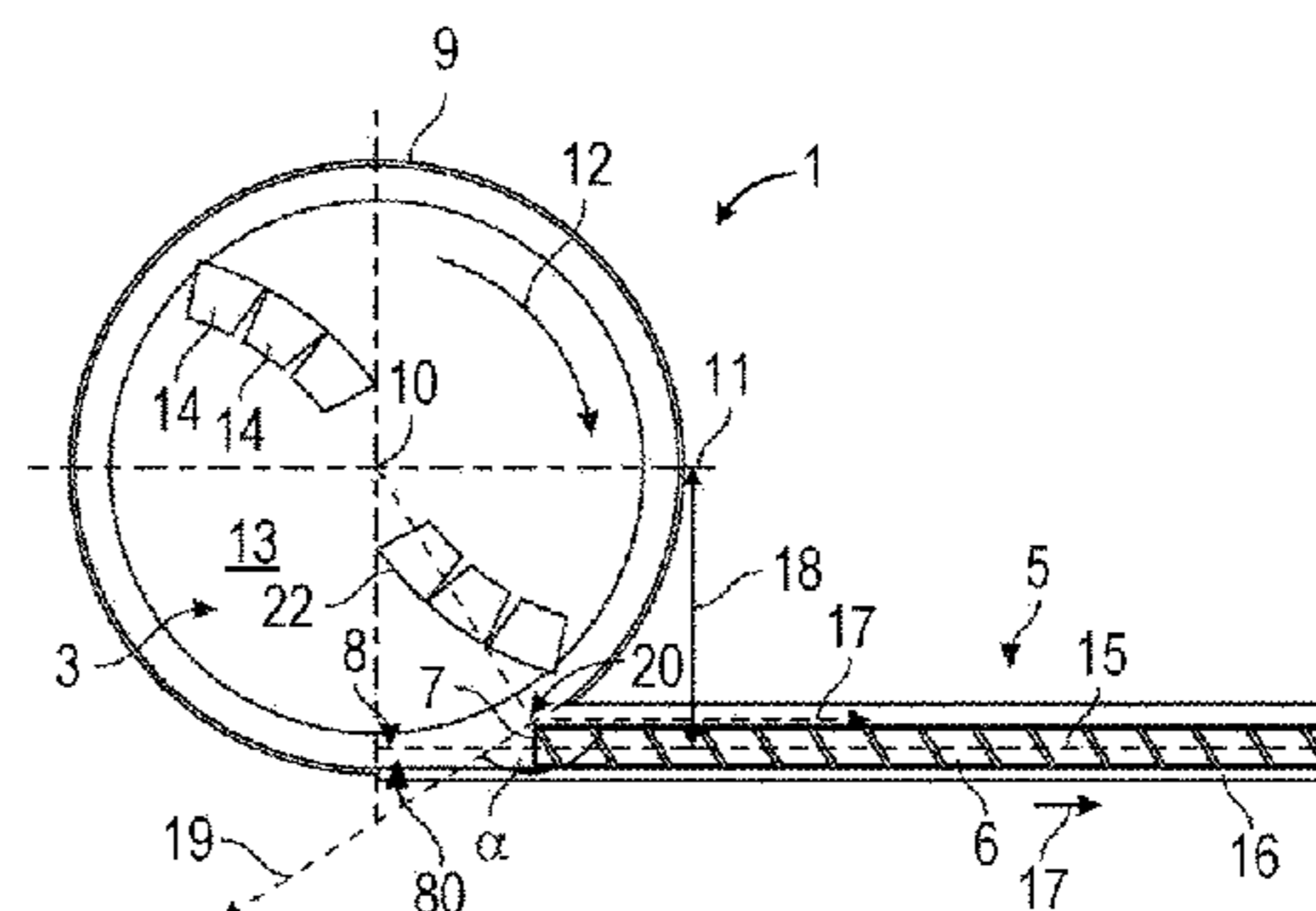
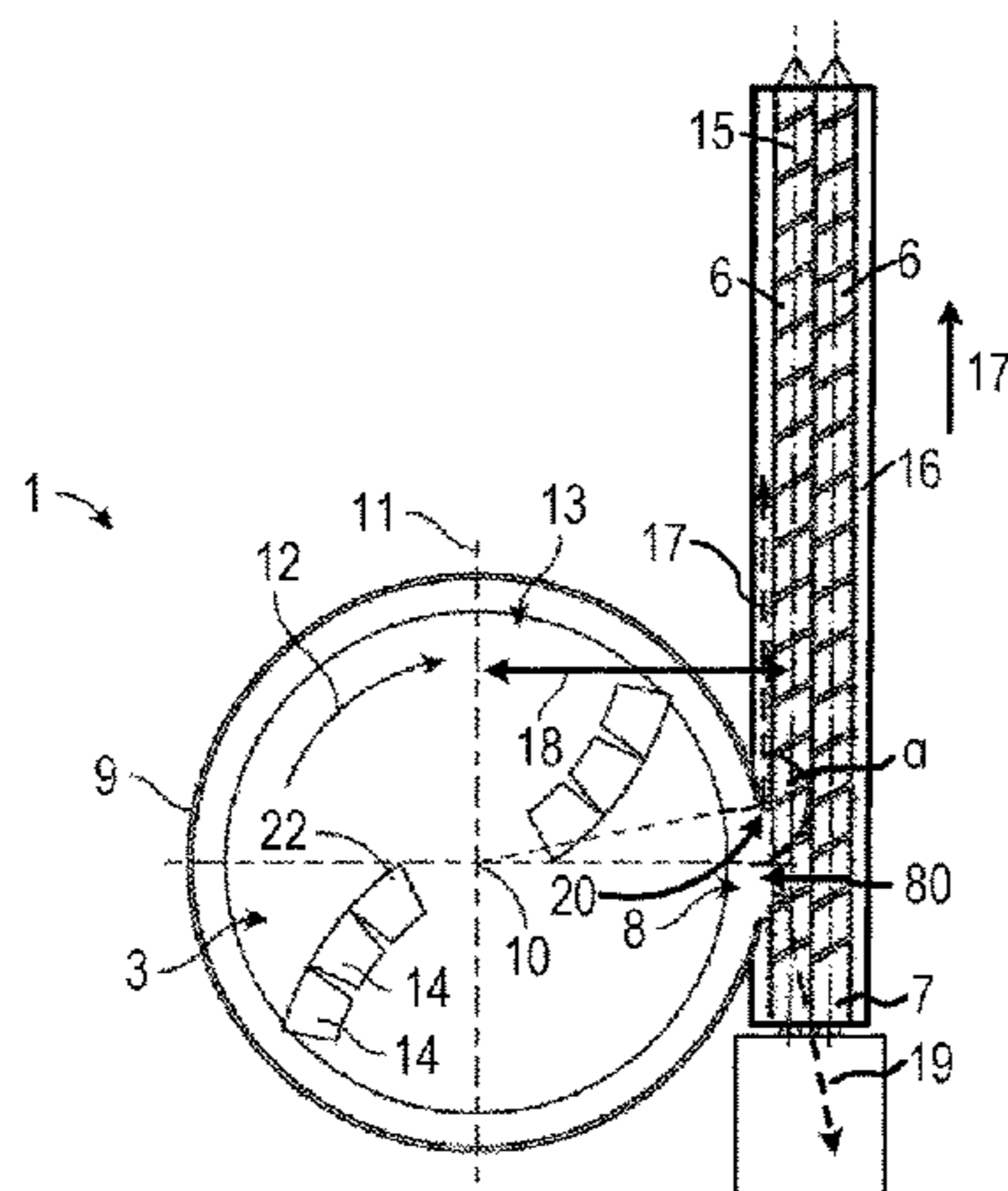
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(57) **ABSTRACT**

The invention relates to an apparatus for the pretreatment and subsequent conveying or plastification of plastics, with a container with a mixing and/or comminution implement that is rotatable around an axis of rotation, wherein, in a side wall, an aperture is formed, through which the plastics

(Continued)



material can be removed, a multiscrew conveyor being provided, with at least two screws rotating in a housing, wherein the imaginary continuation of the longitudinal axis of the conveyor in a direction opposite to the direction of conveying passes the axis of rotation, where, on the outflow side, there is an offset distance between the longitudinal axis of the screw closest to the container and the radius that is parallel to the longitudinal axis, and in that the two screws closest to the intake aperture are counter-rotating relative to one another.

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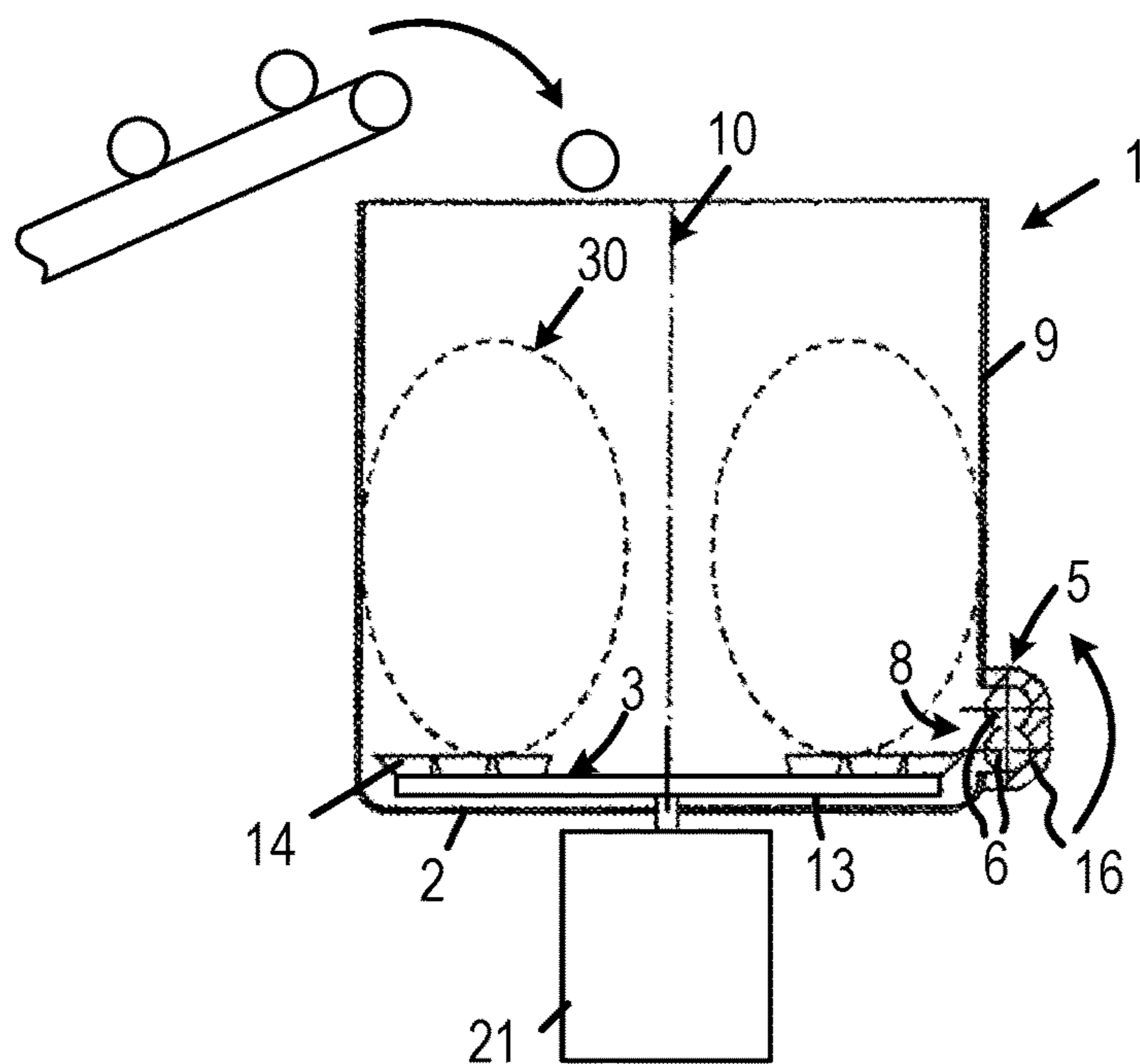
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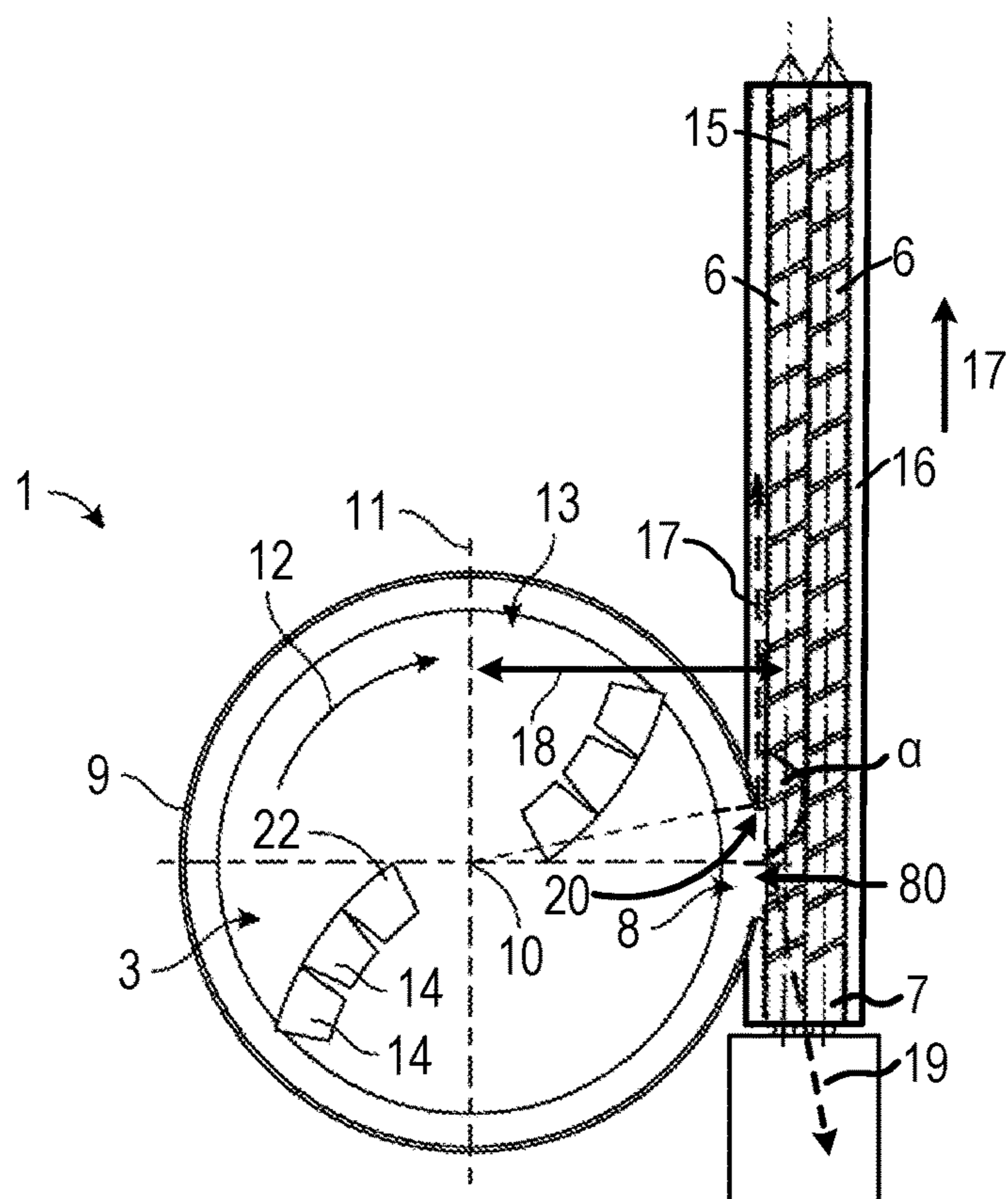
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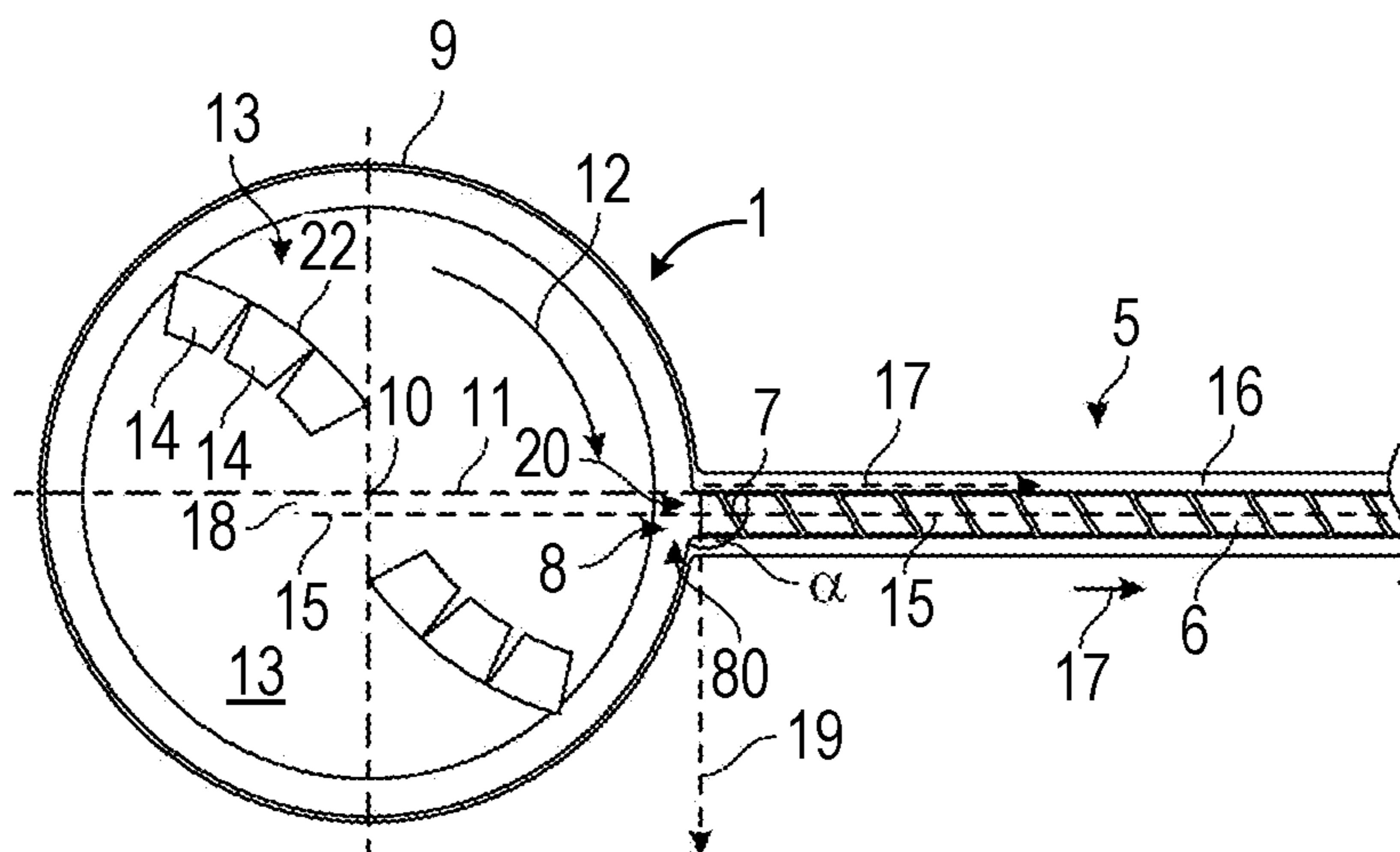
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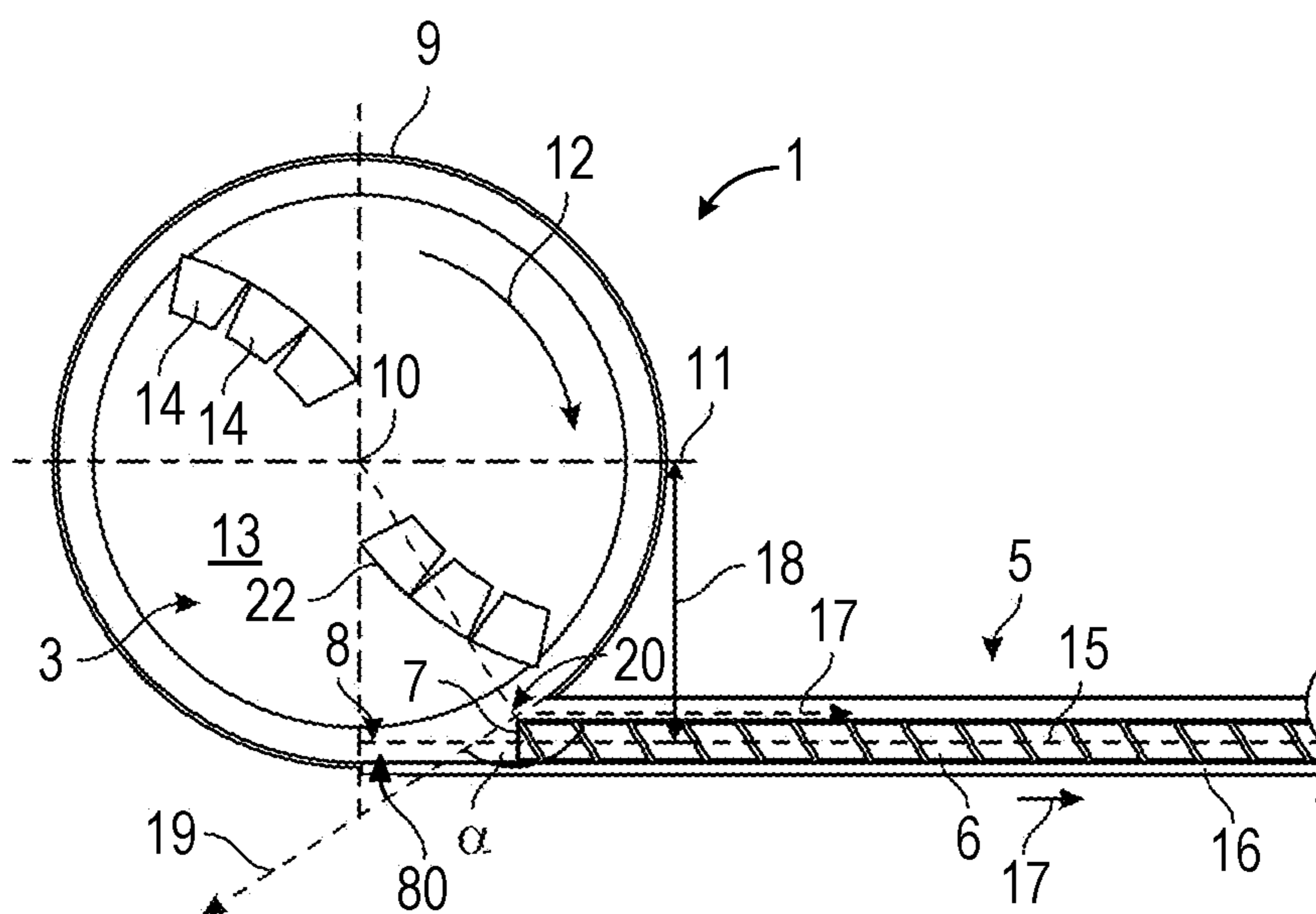
**FIG. 1**



**FIG. 2**



**FIG. 3**



**FIG. 4**

# APPARATUS FOR THE PRETREATMENT AND SUBSEQUENT CONVEYING, PLASTIFICATION, OR AGGLOMERATION OF PLASTICS

This application is a U.S. National Phase of International Application No. PCT/AT2012/050150, filed Oct. 12, 2012, which claims priority to Austrian Patent Application No. A 1500/2011, filed Oct. 14, 2011, the disclosures of which are incorporated by reference herein.

## BACKGROUND

The invention relates to an apparatus for the pretreatment and subsequent conveying, plastification, or agglomeration of plastics.

The prior art reveals numerous similar apparatuses of varying design, comprising a receiver or cutter compactor for the comminution, heating, softening and treatment of a plastics material to be recycled, and also, attached thereto, a conveyor or extruder for the melting of the material thus prepared. The aim here is to obtain a final product of the highest possible quality, mostly in the form of pellets.

By way of example, EP 123 771 or EP 303 929 describe apparatuses with a receiver (receiving container) and, attached thereto, an extruder, where the plastics material introduced into the receiver is comminuted through rotation of the comminution and mixing implements and is fluidized, and is simultaneously heated by the energy introduced. A mixture with sufficiently good thermal homogeneity is thus formed. This mixture is discharged after an appropriate residence time from the receiver into the screw-based extruder, and is conveyed and, during this process, plastified or melted. The arrangement here has the screw-based extruder approximately at the level of the comminution implements. The softened plastics particles are thus actively forced or stuffed into the extruder by the mixing implements.

It is also known in principle to use twin-screw extruders and to attach these to such cutter compactors.

Many of these designs, which have been known for a long time, however, are unsatisfactory in respect of the quality of the treated plastics material obtained at the outgoing end of the screw, and/or in respect of the throughput of the screw. Particularly when using twin screws, special considerations apply which are not transferable from the results obtained with single screws.

Depending on the axial spacing between the screws and their relative direction of rotation, a distinction can be made between co-rotating and counter-rotating as well as tangential and intermeshing twin-screw conveyors or extruders.

In the case of counter-rotating screws, the two screws rotate in opposite directions.

Each of these types has particular fields of use and intended uses. In co-rotating twin-screw extruders, the conveying and the build-up of pressure are brought about in essence by the friction of the material rotating with the screw against the stationary housing wall, and the conveying results mainly from a drag flow. In counter-rotating twin-screw extruders, on the other hand, the principle of forced conveying is predominant.

Critical to the end quality of the product are, firstly, the quality of the pretreated or softened polymer material that enters the conveyor or extruder from the cutter compactor, and, additionally, the situation at intake and on conveying or, where appropriate, extrusion. Relevant factors here include the length of the individual regions or zones of the screw,

and also the screw parameters, such as, for example, screw thickness, flight depths, and so on.

In the case of the present cutter compactor/conveyor combinations, accordingly, there are particular circumstances, since the material which enters the conveyor is not introduced directly, without treatment and cold, but instead has already been pretreated in the cutter compactor, viz. heated, softened and/or partly crystallized, etc. This is a co-determining factor for the intake and for the quality of the material.

The two systems—that is, the cutter compactor and the conveyor—exert an influence on one another, and the outcomes of the intake and of the further conveying, and compaction, where appropriate, are heavily dependent on the pretreatment and the consistency of the material.

One important region, accordingly, is the interface between the cutter compactor and the conveyor, in other words the region in which the homogenized pretreated material is passed from the cutter compactor into the conveyor or extruder. On the one hand, this is a purely mechanical problem area, requiring the coupling to one another of two differently operating devices. Moreover, this interface is tricky for the polymer material as well, since at this point the material is usually, close to the melting range, in a highly softened state, but is not allowed to melt. If the temperature is too low, then there are falls in the throughput and the quality; if the temperature is too high, and if unwanted melting occurs at certain places, then the intake becomes blocked.

Furthermore, precise metering and feeding of the conveyor is difficult, since the system is a closed system and there is no direct access to the intake; instead, the feeding of the material takes place from the cutter compactor, and therefore cannot be influenced directly, via a gravimetric metering device, for example.

It is therefore critical to design this transition not only in a mechanically considered way, in other words with an understanding of the polymer properties, but at the same time to consider the economics of the overall operation—in other words, high throughput and appropriate quality. The preconditions to be observed here are in some cases mutually contradictory.

Counter-rotating multiscrew or twin-screw conveyors generally have a very good intake behaviour. However, the back-ventilation at the charging aperture is poor. The amount of shear and the rate of shear or the introduction of energy into the material of a counter-rotating twin screw is nevertheless low. The distributive mixing effect of such systems is also known from experience to be worse than in the case of a single screw and co-rotating twin screws. With such systems, however, it is possible to build up a suitable pressure for connecting appropriate implements, such as e.g. profile nozzles, at the extruder end.

Specifically in systems in which a conveyor or extruder is connected to a cutter compactor, the intake or feeding into the twin-screw conveyor is far from easily adjustable and e.g. the metering cannot take place via a gravimetric metering device. In contrast, in the cutter compactor, the circulating mixing and comminution implements give rise to a continuous feeding of the pretreated, softened particles or a continuous material flow towards the intake aperture of the conveyor or extruder.

Added to this is the fact that a further common feature of the known devices is that the direction of conveying or of rotation of the mixing and comminution implements, and therefore the direction in which the particles of material circulate in the receiver, and the direction of conveying of

the extruder, in particular of an extruder, are in essence identical or have the same sense. This arrangement, selected intentionally, was the result of the desire to maximize stuffing of the material into the screw, or to force-feed the screw. This concept of stuffing the particles into the conveying screw or extruder screw in the direction of conveying of the screw was also very obvious and was in line with the familiar thinking of the person skilled in the art, since it means that the particles do not have to reverse their direction of movement and there is therefore no need to exert any additional force for the change of direction. An objective here, and in further derivative developments, was always to maximize screw fill and to amplify this stuffing effect. By way of example, attempts have also been made to extend the intake region of the extruder in the manner of a cone or to curve the comminution implements in the shape of a sickle, so that these can act like a trowel in feeding the softened material into the screw. Displacement of the extruder, on the inflow side, from a radial position to a tangential position in relation to the container further amplified the stuffing effect, and increased the force with which the plastics material from the circulating implement was conveyed or forced into the extruder.

Apparatuses of this type are in principle capable of functioning, and they operate satisfactorily, although with recurring problems:

By way of example, an effect repeatedly observed with materials with low energy content, e.g. PET fibres or PET foils, or with materials which at a low temperature become sticky or soft, e.g. polylactic acid (PLA) is that when, intentionally, stuffing of the plastics material into the intake region of the extruder or conveyor, under pressure, is achieved by components moving in the same sense, this leads to premature melting of the material immediately after, or else in, the intake region of the extruder or of the screw. This firstly reduces the conveying effect of the extruder, and secondly there can also be some reverse flow of the said melt into the region of the cutter compactor or receiver, with the result that flakes that have not yet melted adhere to the melt, and in turn the melt thus cools and to some extent solidifies, with resultant formation of a clump or conglomerate made of to some extent solidified melt and of solid plastics particles. This causes blockage on the intake of the extruder and caking of the mixing and comminution implements. A further consequence is reduction of the throughput or quantitative output of the conveyor or extruder, since adequate filling of the screw is no longer achieved.

Another possibility here is that movement of the mixing and comminution implements is prevented. In such cases, the system normally has to be shut down and thoroughly cleaned.

Problems also occur with polymer materials which have already been heated in the cutter compactor up to the vicinity of their melting range. If overfilling of the intake region occurs here, the material melts and intake is impaired.

Problems are also encountered with fibrous materials that are mostly orientated and linear, with a certain amount of longitudinal elongation and low thickness or stiffness, for example plastics foils cut into strips. A main reason for this is that the elongate material is retained at the outflow end of the intake aperture of the screw, where one end of the strip protrudes into the receiver and the other end protrudes into the intake region. Since the mixing implements and the screw are moving in the same sense or exert the same conveying-direction component and pressure component on the material, both ends of the strip are subjected to tension and pressure in the same direction, and release of the strip

becomes impossible. This in turn leads to accumulation of the material in the said region, to a narrowing of the cross section of the intake aperture, and to poorer intake performance and, as a further consequence, to reduced throughput. The increased feed pressure in this region can moreover cause melting, and this in turn causes the problems mentioned in the introduction.

For counter-rotating twin-screw conveyors too, therefore, the intake is sensitive.

## SUMMARY

It is therefore an object of the present invention to overcome the disadvantages mentioned and to improve an apparatus of the type described in the introduction in such a way that even sensitive or strip-shaped materials can be taken in by the screws without any problem and in such a way as to permit processing or treatment of these materials to give material of high quality, with high throughput.

The characterizing features of certain embodiments achieve this object in an apparatus of the type mentioned in the introduction.

A first provision here is that the imaginary continuation of the central longitudinal axis of the conveyor, in particular extruder, if this has only a single screw, or the longitudinal axis of the screw closest to the intake aperture, if the conveyor has more than one screw, in the direction opposite to the direction of conveying of the conveyor, passes, and does not intersect, the axis of rotation, where, on the outflow side, there is an offset distance between the longitudinal axis of the conveyor, if this has a single screw, or the longitudinal axis of the screw closest to the intake aperture, and the radius that is associated with the container and that is parallel to the longitudinal axis and that proceeds outwards from the axis of rotation of the mixing and/or comminution implement in the direction of conveying of the conveyor.

The direction of conveying of the mixing implements and the direction of conveying of the conveyor are therefore no longer in the same sense, as is known from the prior art, but instead are at least to a small extent in the opposite sense, and the stuffing effect mentioned in the introduction is thus reduced. The intentional reversal of the direction of rotation of the mixing and comminution implements in comparison with apparatuses known hitherto reduces the feed pressure on the intake region, and the risk of overfilling decreases. In this way, excess material is not stuffed or trowelled with excess pressure into the intake region of the conveyor, but instead, in contrast, there is in fact in turn a tendency to remove excess material from that region, in such a way that although there is always sufficient material present in the intake region, the additional pressure exerted is small or almost zero. This method can provide adequate filling of the screw and constant intake of sufficient material by the screw, without any overfilling of the screw with, as a further consequence, local pressure peaks where the material could melt.

Melting of the material in the region of the intake is thus prevented, and operating efficiency is therefore increased, maintenance intervals are therefore lengthened, and downtime due to possible repairs and cleaning measures is reduced.

By virtue of the reduced feed pressure, displaceable elements which can be used in a known manner to regulate the degree of filling of the screw react markedly more sensitively, and the degree of filling of the screw can be adjusted with even greater precision. This makes it easier to find the ideal point at which to operate the system, in

particular for relatively heavy materials, for example regrind made of high-density polyethylene (HDPE) or PET.

Surprisingly and advantageously it has moreover been found that operation in the opposite sense, according to the invention, improves intake of materials which have already been softened almost to the point of melting. In particular when the material is already in a doughy or softened condition, the screw cuts the material from the doughy ring adjacent to the container wall. In the case of a direction of rotation in the direction of conveying of the screw, this ring would instead be pushed onward, and removal of an outer layer by the screw would not be possible, with resultant impairment of intake. The reversal of the direction of rotation, according to the invention, avoids this.

Furthermore, the retention or accumulation phenomena formed in the case of the treatment of the materials which have been described above and are in strip form or fibrous can be resolved more easily, or do not occur at all, since, at the aperture edge situated in the direction of rotation of the mixing implements on the outflow side or downstream, the direction vector for the mixing implements and the direction vector for the conveyor point in almost opposite directions, or in directions that at least to a small extent have opposite sense, and an elongate strip cannot therefore become curved around, and retained by, the said edge, but instead becomes entrained again by the mixing vortex in the receiver.

The overall effect of the design according to the invention is that intake performance is improved and throughput is markedly increased. The stability and performance of the entire system made of cutter compactor and conveyor is thus increased.

The counter-rotating twin screw profits very particularly from the material from the cutter compactor that has been prehomogenized by the counter-rotating implements. Furthermore, a system such as this is particularly suitable for materials that are sensitive to temperature and shear, such as e.g. PLA/wood composites. With the lower stuffing force due to the direction of rotation, the cutter compactor gently stuffs into the counter-rotating twin screw, which per se is easy to fill, and thus ensures that there is no overfilling and no premature melting. The heated material, which has already been prehomogenized, is then melted by the gently operating counter-rotating twin screw.

The melt is then usually processed immediately into a profile, particularly when WPC (Wood Plastic Compounds) and in particular PLA/long wood fibre composites are involved. Long wood fibres or natural fibres are extremely difficult to introduce into extrusion systems. The particular direction of rotation of the implements of the cutter compactor ensures a safe filling of said fibres, which may account for up to 70-80% by weight of the total composite.

Further advantageous embodiments of the invention are described via the following features:

In particular, it is advantageous if precisely two screws are provided or the conveyor is designed as a counter-rotating twin-screw extruder. The most reliable results can be achieved in this case.

According to one preferred further development of the invention, it is provided that the screws are cylindrical and are parallel to one another, and that the conveyor is designed as a parallel twin-screw conveyor, in particular as a twin-screw extruder.

According to an alternative further development, it is provided that the screws are conical, and that the conveyor is designed as a conical twin-screw conveyor or extruder. Such a conveyor is particularly suitable for receiving light-weight bulk goods.

It may also be provided that one of the screws is longer than the other(s).

It may further be provided that the screws are intermeshing or tangential at least in the region of the intake aperture, so as to be able to meet the needs of the material to be treated.

According to a further space-saving advantageous embodiment with effective intake, it is provided that the cross sections of the screws lie vertically one above the other and the screws in the immediate area of the intake aperture are arranged in particular symmetrically with respect to the centre of the intake aperture and are spaced at equal distances away from the plane of the intake aperture.

As an alternative, it may be provided that the cross sections of the screws lie obliquely one above the other or horizontally one next to the other and only the screw closest to the intake aperture is arranged in the immediate area of the intake aperture.

In this connection, it is particularly advantageous for the intake behaviour if the screw closest to the intake aperture, as seen from the start of the screws closest to the intake or container, possibly on the motor side, or from the intake aperture, towards the end or the discharge aperture of the conveyor, rotates in the clockwise direction.

This is particularly advantageous for regrind since regrind is usually very free-flowing. In known apparatuses with a conventional direction of rotation of the screw, the screw is filled solely by the effect of the shear force and the implements have only little effect. As a result, it is difficult to introduce energy into the material since often specifically the outer implements have to be greatly reduced in height or often even omitted. The melting performance in the screw suffers as a result, since the material has not been sufficiently heated in the cutter compactor. This is even more critical in the case of regrind since regrind is relatively thick in comparison to films and it is even more important for the particles to be heated in their interior as well.

If the direction of rotation of the screw is reversed, the screw is no longer filled automatically and the implements are necessary for conveying the material into the upper region of the screw. As a result, it is also possible to introduce sufficient energy into the material to facilitate a possible subsequent melting. This consequently gives rise to an increased throughput and a better quality since, due to fewer cold particles, the shear in the screw can be reduced and this in turn helps to achieve improved MFI values.

Preferably, both screws have the same diameter.

According to an advantageous development of the invention, the conveyor is arranged on the receiver in such a way that the scalar product of the direction vector (direction vector that is associated with the direction of rotation) that is tangential to the circle described by the radially outermost point of the mixing and/or comminution implement or to the plastics material transported past the aperture and that is normal to a radius of the receiver, and that points in the direction of rotation or of movement of the mixing and/or comminution implement and of the direction vector that is associated with the direction of conveying of the conveyor at each individual point or in the entire region of the aperture or at each individual point or in the entire region immediately radially in front of the aperture is zero or negative. The region immediately radially in front of the aperture is defined as that region which is in front of the aperture and at which the material is just about to pass through the aperture but has not yet passed the aperture. The advantages mentioned in the introduction are thus achieved, and there is effective avoidance of all types of agglomeration in the

region of the intake aperture, brought about by stuffing effects. In particular here, there is also no dependency on the spatial arrangement of the mixing implements and of the screw in relation to one another, and by way of example the orientation of the axis of rotation does not have to be normal to the basal surface or to the longitudinal axis of the conveyor or of the screw. The direction vector that is associated with the direction of rotation and the direction vector that is associated with the direction of conveying lie within a, preferably horizontal, plane, or in a plane orientated so as to be normal to the axis of rotation.

In another advantageous formation, the angle included between the direction vector that is associated with the direction of rotation of the mixing and/or comminution implement and the direction vector that is associated with the direction of conveying of the conveyor is greater than or equal to  $90^\circ$  and smaller than or equal to  $180^\circ$ , where the angle is measured at the point of intersection of the two direction vectors at the edge that is associated with the aperture and that is situated upstream of the direction of rotation or of movement, in particular at the point that is on the said edge or on the aperture and is situated furthest upstream. This therefore describes the range of angles within which the conveyor must be arranged on the receiver in order to achieve the advantageous effects. In the entire region of the aperture or at each individual point of the aperture, the forces acting on the material are therefore orientated at least to a small extent in an opposite sense, or in the extreme case the orientation is perpendicular and pressure-neutral. At no point of the aperture is the scalar product of the direction vectors of the mixing implements and of the screw positive, and no excessive stuffing effect occurs even in a subregion of the aperture.

Another advantageous formation of the invention provides that the angle included between the direction vector that is associated with the direction of rotation or of movement and the direction vector that is associated with the direction of conveying is from  $170^\circ$  to  $180^\circ$ , measured at the point of intersection of the two direction vectors in the middle of the aperture. This type of arrangement is relevant by way of example when the conveyor is arranged tangentially on the cutter compactor.

In order to ensure that no excessive stuffing effect occurs, the distance, or the offset, between the longitudinal axis and the radius can advantageously be greater than or equal to half of the internal diameter of the housing of the conveyor or of the screw.

It can moreover be advantageous for these purposes to set the distance or offset between the longitudinal axis and the radius to be greater than or equal to 7%, or still more advantageously greater than or equal to 20%, of the radius of the receiver. In the case of conveyors with a prolonged intake region or with grooved bushing or with extended hopper, it can be advantageous for this distance or offset to be greater than or equal to the radius of the receiver. This is particularly true for cases where the conveyor is attached tangentially to the receiver or runs tangentially to the cross section of the container.

In a particularly advantageous embodiment here, the longitudinal axis of the conveyor or of the screw or the longitudinal axis of the screw closest to the intake aperture runs tangentially with respect to the inner side of the side wall of the container, or the inner wall of the housing does so, or the envelope of the screw does so, where it is preferable that there is a drive connected to the end of the screw, and that the screw provides conveying, at its opposite

end, to a discharge aperture which is in particular an extruder head and which is arranged at the end of the housing.

In the case of conveyors that are radially offset, but not arranged tangentially, it is advantageous to provide that the imaginary continuation of the longitudinal axis of the conveyor in a direction opposite to the direction of conveying, at least in sections, passes, in the form of a secant, through the space within the receiver.

It is advantageous to provide that there is immediate and direct connection between the aperture and the intake aperture, without substantial separation or a transfer section, e.g. a conveying screw. This permits effective and non-aggressive transfer of material.

The reversal of the direction of rotation of the mixing and comminution implements circulating in the container can certainly not result from arbitrary action or negligence, and it is not possible—either in the known apparatuses or in the apparatus according to the invention—simply to allow the mixing implements to rotate in the opposite direction, in particular because the arrangement of the mixing and comminution implements is in a certain way asymmetrical or direction-oriented, and their action is therefore only single-sided or unidirectional. If this type of equipment were to be rotated intentionally in the wrong direction, a good mixing vortex would not form, and there would be no adequate comminution or heating of the material. Each cutter compactor therefore has its unalterably prescribed direction of rotation of the mixing and comminution implements.

In this connection, it is particularly advantageous to provide that the manner of formation, set-up, curvature and/or arrangement of the frontal regions or frontal edges that are associated with the mixing and/or comminution implements, act on the plastics material and point in the direction of rotation or of movement, differs when comparison is made with the regions that, in the direction of rotation or of movement, are at the rear or behind.

One advantageous arrangement provides that arranged on the mixing and/or comminution implement are implements and/or blades which perform a heating, comminuting and/or cutting action on the plastics material in the direction of rotation and movement. The implements and/or blades can either have been fastened directly on the shaft or preferably have been arranged on a rotatable implement carrier or, respectively, a carrier disc arranged in particular parallel to the basal surface, or have been formed therein or moulded onto the same, optionally as a single piece.

In principle, the effects mentioned are relevant not only to compressing extruders or agglomerators but also to conveying screws that have no, or less, compressing effect. Here again, local overfeed is avoided.

In another particularly advantageous formation, it is provided that the receiver is in essence cylindrical with a level basal surface and with, orientated vertically in relation thereto, a side wall which has the shape of the jacket of a cylinder. In another simple design, the axis of rotation coincides with the central axis of the receiver. In another advantageous formation, the axis of rotation or the central axis of the container have been orientated vertically and/or normally in relation to the basal surface. These particular geometries optimize intake performance, with an apparatus design that provides stability and simple construction.

In this connection it is also advantageous to provide that the mixing and/or comminution implement or, if a plurality of mutually superposed mixing and/or comminution implements have been provided, the lowest mixing and/or comminution implement closest to the base is arranged at a small distance from the basal surface, in particular in the region of

the lowest quarter of the height of the receiver, and also that the aperture is similarly arranged. The distance here is defined and measured from the lowest edge of the aperture or of the intake aperture to the container base in the edge region of the container. There is mostly some rounding of the edge at the corner, and the distance is therefore measured from the lowest edge of the aperture along the imaginary continuations of the side wall downwards to the imaginary outward continuation of the container base. Distances with good suitability are from 10 to 400 mm.

For the treatment, it is also advantageous if the radially outermost edges of the mixing and/or comminution implements extend right up close to the side wall.

The container does not necessarily have to have a cylindrical shape with circular cross section, even though this shape is advantageous for practical reasons and reasons of manufacturing technology. When container shapes that deviate from the cylindrical shape with circular cross section, examples being containers having the shape of a truncated cone or cylindrical containers which, in plan view, are elliptical or oval, a calculation is required for conversion to a cylindrical container which has circular cross section and the same volume capacity, on the assumption that the height of this imaginary container is the same as its diameter. Container heights here which are substantially higher than the resultant mixing vortex (after taking into account the distance required for safety) are ignored, since this excess container height is not utilized and it therefore has no further effect on the processing of the material.

The expression conveyor means mainly systems with screws that have non-compressing or decompressing effect, i.e. screws which have purely conveying effect, but also systems with screws that have compressing effect, i.e. extruder screws with agglomerating or plastifying effect.

The expressions extruder and extruder screw in the present text mean extruders or screws used for complete or partial melting of the material, and also extruders used to agglomerate, but not melt, the softened material. Screws with agglomerating effect subject the material to severe compression and shear only for a short time, but do not plastify the material. The outgoing end of the agglomerating screw therefore delivers material which has not been completely melted but which instead is composed of particles incipiently melted only at their surface, which have been caked together as if by sintering. However, in both cases the screw exerts pressure on the material and compacts it.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the invention are apparent from the description of the inventive examples below of the subject matter of the invention, which are not to be interpreted as restricting, and which the drawings depict diagrammatically and not to scale:

FIG. 1 shows a vertical section through an apparatus according to the invention with extruder attached approximately tangentially, said extruder comprising screws arranged one above the other.

FIG. 2 shows a horizontal section through an alternative embodiment with extruder attached approximately tangentially, said extruder comprising conical screws arranged one next to the other.

FIG. 3 shows another embodiment with minimal offset of the extruder.

FIG. 4 shows another embodiment with relatively large offset of the extruder.

#### DETAILED DESCRIPTION

Neither the containers, nor the screws nor the mixing implements are to scale, either themselves or in relation to one another, in the drawings. By way of example, therefore, the containers are in reality mostly larger, or the screws longer, than depicted here.

The cutter compactor-extruder combinations shown from different positions in FIG. 1 and FIG. 2 are very similar in terms of their design and will therefore be described together below. The main difference lies in the arrangement of the screws relative to one another, as will be discussed in detail below.

The advantageous cutter compactor-extruder combinations depicted in FIG. 1 and FIG. 2 for the treatment or recycling of plastics material each have a cylindrical container or cutter compactor or shredder 1 with circular cross section, with a level, horizontal basal surface 2 and with a vertical side wall 9 oriented normally thereto with the shape of a cylinder jacket.

Arranged at a small distance from the basal surface 2, at most at about 10 to 20%, or optionally less, of the height of the side wall 9—measured from the basal surface 2 to the uppermost edge of the side wall 9—is an implement carrier 13 or a level carrier disc orientated parallel to the basal surface 2, which carrier or disc can be rotated, in the direction 12 of rotation or of movement indicated by an arrow 12, around a central axis 10 of rotation, which is simultaneously the central axis of the container 1. A motor 21, located below the container 1, drives the carrier disc 13. On the upper side of the carrier disc 13, blades or implements, e.g. cutter blades, 14 have been arranged, and together with the carrier disc 13 form the mixing and/or comminution implement 3.

As indicated in the diagram, the blades 14 are not arranged symmetrically on the carrier disc 13, but instead have a particular manner of formation, set-up or arrangement on their leading convex frontal edges 22 facing in the direction 12 of rotation or of movement, so that they can have a specific mechanical effect on the plastics material. The radially outermost edges of the mixing and comminution implements 3 reach a point which is relatively close to, about 5% of the radius 11 of the container 1 from, the inner surface of the side wall 9.

The container 1 has, near the top, a charging aperture through which the product to be processed, e.g. portions of plastics foils, is charged by way of example by means of a conveying device in the direction of the arrow. The container 1 can, as an alternative, be a closed container and capable of evacuation at least as far as an industrial vacuum, the material being introduced by way of a system of valves. The said product is received by the circulating mixing and/or comminution implements 3 and is raised to form a mixing vortex 30, where the product rises along the vertical side wall 9 and, approximately in the region of the effective container height H, falls back again inward and downward into the region of the centre of the container, under gravity. The effective height H of the container 1 is approximately the same as its internal diameter D. In the container 1, a mixing vortex is thus formed, in which the material is circulated in a vortex both from top to bottom and also in the direction 12 of rotation. By virtue of this particular arrangement of the mixing and comminution elements 3 or the blades 14, this type of apparatus can therefore be operated

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only with the prescribed direction 12 of rotation or movement, and the direction 12 of rotation cannot be reversed readily or without additional changes.

The circulating mixing and comminution implements 3 comminute and mix the plastics material introduced, and thereby heat and soften it by way of the mechanical frictional energy introduced, but do not melt it. After a certain residence time in the container 1, the homogenized, softened, doughy but not molten material is, as described in detail below, removed from the container 1 through an aperture 8, passed into the intake region of an extruder 5, and received by a screw 6 there and subsequently melted.

At the level of the, in the present case single, comminution and mixing implement 3, the said aperture 8 is formed in the side wall 9 of the container 1, and the pretreated plastics material can be removed from the interior of the container 1 through this aperture. The material is passed to a twin-screw extruder 5 arranged tangentially on the container 1, where the housing 16 of the extruder 5 has, situated in its jacket wall, an intake aperture 80 for the material to be received by the screws 6. This type of embodiment has the advantage that the screws 6 can be driven from the lower ends 7 in the drawing by a drive, depicted only diagrammatically, in such a way that the upper ends of the screws 6 in the drawing can be kept free from the drive. The discharge aperture for the plastified or agglomerated plastics material conveyed by the screws 6 can therefore be arranged at this upper end, e.g. in the form of an extruder head not depicted. The plastics material can therefore be conveyed without deflection by the screws 6 through the discharge aperture; this is not readily possible in the embodiments according to FIGS. 3 and 4.

There is a connection for conveying of material or for transfer of material between the intake aperture 80 and the aperture 8, and in the present case this connection to the aperture 8 is direct and immediate and involves no prolonged intervening section and no separation. All that is provided is a very short transfer region.

In the housing 16, two cylindrical screws 6 with compressing effect are each mounted such as to be able to rotate around their longitudinal axis 15. As an alternative, the screws may also be conical, as shown in FIG. 2. The extruder 5 conveys the material in the direction of the arrow 17. The extruder 5 is a conventional twin-screw extruder known per se in which the softened plastics material is compressed and thus melted, and the melt is then discharged at the opposite end, at the extruder head.

In the embodiment according to FIG. 1 the two screws 6 are arranged vertically one above the other, and in the embodiment according to FIG. 2 the two screws 6 are arranged horizontally one next to the other.

The two screws 6 rotate in opposite directions and are therefore counter-rotating screws.

The mixing and/or comminution implements 3 or the blades 14 are at approximately the same level as the central longitudinal axis 15 of the lowest screw 6 in FIG. 1 or of the screw 6 adjacent to the intake aperture 80. The outermost ends of the blades 14 have adequate separation from the flights of the screws 6.

In the embodiment according to FIGS. 1 and 2, the extruder 5 is, as mentioned, attached tangentially to the container 1, or runs tangentially in relation to its cross section. In the drawings, the imaginary continuation of the central longitudinal axis 15 of the lower screw 6 or of the screw 6 adjacent to the intake aperture 80 in a direction opposite to the direction 17 of conveying of the extruder 5 towards the rear passes the axis 10 of rotation and does not

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intersect it. On the outflow side, there is an offset distance 18 between the longitudinal axis 15 of said screw 6 and the radius 11 that is associated with the container 1 and that is parallel to the longitudinal axis 15 and that proceeds outwards from the axis 10 of rotation of the mixing and/or comminution implement 3 in the direction 17 of conveying of the conveyor 5. In the present case, the imaginary continuation of the longitudinal axis 15 towards the rear does not pass through the space within the container 1, but instead passes it at a short distance.

The distance 18 is somewhat greater than the radius of the container 1. There is therefore a slight outward offset of the extruder 5, or the intake region is somewhat deeper.

The expressions "opposite", "counter-" and "in an opposite sense" here mean any orientation of the vectors with respect to one another which is not acute-angled, as explained in detail below.

In other words, the scalar product of a direction vector 19 which is associated with the direction 12 of rotation and the orientation of which is tangential to the circle described by the outermost point of the mixing and/or comminution implement 3 or tangential to the plastics material passing the aperture 8, and which points in the direction 12 of rotation or movement of the mixing and/or comminution implements 3, and of a direction vector 17 which is associated with the direction of conveying of the extruder 5 and which proceeds in the direction of conveying parallel to the central longitudinal axis 15 of the screw 6 is everywhere zero or negative, at each individual point of the aperture 8 or in the region radially immediately in front of the aperture 8, and is nowhere positive.

In the case of the intake aperture in FIGS. 1 and 2, the scalar product of the direction vector 19 for the direction 12 of rotation and of the direction vector 17 for the direction of conveying is negative at every point of the aperture 8.

The angle  $\alpha$  between the direction vector 17 for the direction of conveying and the direction vector for the direction 19 of rotation, measured at the point 20 that is associated with the aperture 8 and situated furthest upstream of the direction 12 of rotation, or at the edge associated with the aperture 8 and situated furthest upstream, is approximately maximally about  $170^\circ$ .

As one continues to proceed downwards along the aperture 8 in FIG. 2, i.e. in the direction 12 of rotation, the oblique angle between the two direction vectors continues to increase. In the centre of the aperture 8, the angle between the direction vectors is about  $180^\circ$  and the scalar product is maximally negative, and further downwards from there the angle indeed becomes  $>180^\circ$  and the scalar product in turn decreases, but still remains negative. However, these angles are no longer termed angles  $\alpha$ , since they are not measured at point 20.

An angle  $\beta$ , not included in the drawing in FIG. 2, measured in the centre of the aperture 8, between the direction vector for the direction 19 of rotation and the direction vector for the direction 17 of conveying is about  $178^\circ$  to  $180^\circ$ .

The apparatus according to FIG. 2 represents the first limiting case or extreme value. This type of arrangement can provide a very non-aggressive stuffing effect or a particularly advantageous feed, and this type of apparatus is particularly advantageous for sensitive materials which are treated in the vicinity of the melting range, or for product in the form of long strips.

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FIGS. 3 and 4 serve only for illustrating the connection possibilities of the extruder with regard to the direction of rotation of the implements. The values for L, B and A are not depicted.

FIG. 3 shows an alternative embodiment in which an extruder 5 comprising two counter-rotating screws 6 arranged vertically one above the other is not attached tangentially to the container 1 but instead is attached by its end 7. The screws 6 and the housing 16 of the extruder 5 have been adapted in the region of the aperture 8 to the shape of the inner wall of the container 1, and have been offset backwards so as to be flush. No part of the extruder 5 or of the screws 6 protrudes through the aperture 8 into the space within the container 1.

The distance 18 here corresponds to about 5 to 10% of the radius 11 of the container 1 and to about half of the internal diameter d of the housing 16. This embodiment therefore represents the second limiting case or extreme value with the smallest possible offset or distance 18, where the direction 12 of rotation or of movement of the mixing and/or comminution implements 3 is at least slightly opposite to the direction 17 of conveying of the extruder 5, and specifically across the entire area of the aperture 8.

The scalar product in FIG. 3 at that threshold point 20 situated furthest upstream is precisely zero, where this is the point located at the edge that is associated with the aperture 8 and situated furthest upstream. The angle  $\alpha$  between the direction vector 17 for the direction of conveying and the direction vector for the direction 19 of rotation, measured at point 20 in FIG. 3, is precisely  $90^\circ$ . If one proceeds further downwards along the aperture 8, i.e. in the direction of rotation, the angle between the direction vectors becomes ever greater and becomes an oblique angle  $>90^\circ$ , and at the same time the scalar product becomes negative. However, at no point, or in no region of the aperture 8, is the scalar product positive, or the angle smaller than  $90^\circ$ . No local overfeed can therefore occur even in a subregion of the aperture 8, and no detrimental excessive stuffing effect can occur in a region of the aperture 8.

This also represents a decisive difference in relation to a purely radial arrangement, since there would be an angle  $\alpha < 90^\circ$  at point 20 or at the edge 20' in a fully radial arrangement of the extruder 5, and those regions of the aperture 8 situated, in the drawing, above the radius 11 or upstream thereof or on the inflow side thereof would have a positive scalar product. It would thus be possible for locally melted plastics product to accumulate in these regions.

FIG. 4 depicts another alternative embodiment in which an extruder 5 comprising two counter-rotating screws 6 arranged vertically one above the other is somewhat further offset than in FIG. 3 on the outflow side, but still not tangentially as in FIGS. 1 and 2. In the present case, as also in FIG. 3, the rearward imaginary continuation of the longitudinal axis of the screws 6 passes through the space within the container 1 in the manner of a secant. As a consequence of this, the aperture 8 is—measured in the circumferential direction of the container 1—wider than in the embodiment according to FIG. 3. The distance 18 is also correspondingly greater than in FIG. 3, but somewhat smaller than the radius 11. The angle  $\alpha$  measured at point 20 is about  $150^\circ$ , and the stuffing effect is therefore reduced in comparison with the apparatus of FIG. 3; this is more advantageous for certain sensitive polymers. The inner wall of the housing 16 or the right-hand-side inner edge, as seen from the container 1, is tangential to the container 1, and therefore, unlike in FIG. 3, there is no oblique transitional edge. At this point that is associated with the aperture

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8 and situated furthest downstream, on the extreme left-hand side in FIG. 4, the angle is about  $180^\circ$ .

The invention claimed is:

1. An apparatus for the pretreatment and subsequent conveying of a plastic material, the apparatus comprising:
  - a container configured to hold the plastic material to be pretreated;
  - at least one mixing and/or comminution implement within the container, wherein the mixing and/or comminution implement is configured to pretreat the plastic material and comprises at least one blade configured to rotate around an axis of rotation, wherein the blade has a convex edge, and wherein pretreating the plastic material comprises at least one of mixing, heating, and comminuting the plastic material,
  - wherein the container comprises an aperture through which the pretreated plastic material exits the container, wherein the aperture is formed in a side wall of the container adjacent to the mixing and/or comminution implement;
  - at least one multiscrew conveyor configured to receive the pretreated plastic material through the aperture, the multiscrew conveyor comprising:
    - a housing comprising an intake configured to receive the pretreated plastic material from the container, and
    - first and second screws in the housing, wherein the first and second screws are configured to rotate in opposite directions and to convey the pretreated plastic material in a conveying direction away from the container,
    - wherein the imaginary continuation of the central longitudinal axis of the first screw is offset from the axis of rotation of the mixing and/or comminution implement at a point nearest the axis of rotation by an offset distance; and
  - a motor configured to rotate the mixing and/or comminution implement, wherein the motor is structured to rotate the mixing and/or comminution implement such that the convex edge of the blade of the mixing and/or comminution implement leads during rotation, wherein the motor is structured to rotate in a direction which causes the motion of the convex edge to be described by a direction vector such that when the convex edge is nearest the aperture, the motion vector describing the motion of the convex edge nearest the aperture is either perpendicular to the conveying direction or has a vector component which has a direction opposite the conveying direction.
2. The apparatus according to claim 1, wherein precisely two screws are provided.
3. The apparatus according to claim 1, wherein the screws are substantially cylindrical and are parallel to one another, and wherein the conveyor is a parallel twin-screw conveyor.
4. The apparatus according to claim 1, wherein the screws comprise two conical screws.
5. The apparatus according to claim 1, wherein the screws are intermeshing or tangential at least in the region of the intake.
6. The apparatus according to claim 1, wherein the screws lie vertically one above the other and the screws in the immediate area of the intake are arranged symmetrically with respect to the center of the intake and are spaced at equal distances away from the plane of the intake.

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7. The apparatus according to claim 1, wherein the screws lie one above the other or horizontally one next to the other and only the screw closest to the intake is arranged in the immediate area of the intake.

8. The apparatus according to claim 1, wherein the screw closest to the intake or the lowermost screw, as seen from the start of the screw closest to the intake or container or from the intake, towards a discharge aperture of the conveyor, rotates in the clockwise direction.

9. The apparatus according to claim 1, wherein the conveyor is in contact with the container and the scalar product of the direction vector describing the motion of the blade nearest the aperture when the blade is adjacent the aperture, and another direction vector describing the conveying of the conveyor is zero or negative.

10. The apparatus according to claim 1 wherein the angle ( $\alpha$ ) between the direction vector describing the motion of the portion of the convex edge nearest the aperture when the convex edge is adjacent the aperture, and another direction vector describing the direction of the conveying of the conveyor is greater than or equal to  $90^\circ$  and less than or equal to  $180^\circ$ .

11. The apparatus according to claim 1, wherein the angle ( $\beta$ ) between the direction vector describing the motion of the portion of the convex edge when the convex edge is adjacent the aperture, and the conveying direction is from  $170^\circ$  to  $180^\circ$ .

12. The apparatus according to claim 1, wherein the offset distance is at least one of:

- greater than or equal to half of the internal diameter of the first screw, and
- greater than or equal to 7% of the radius of the container.

## 16

13. The apparatus according to claim 1, wherein the imaginary continuation of the longitudinal axis of the first screw passes through the container.

14. The apparatus according to claim 1, wherein the conveyor is attached tangentially to the container, or wherein the longitudinal axis of the first screw runs tangentially with respect to the inner side of the side wall of the container, or the inner wall of the housing runs tangentially with respect to the inner side of the side wall of the container, or an envelope defined by the rotation of the first screw runs tangentially with respect to the inner side of the side wall of the container,

wherein the apparatus further comprises:

- a drive connected to the first and second screws,
- a discharge aperture in the housing of the conveyor, and
- an extruder head connected to the discharge aperture.

15. The apparatus according to claim 1, wherein there is immediate and direct connection between the aperture and the intake aperture, without substantial separation, and without a transfer section or a conveying screw.

16. The apparatus according to claim 1, wherein the blade is configured to perform a comminuting, cutting and heating action on the plastic material, wherein the blade is on a rotatable implement carrier, which is arranged in parallel to a basal surface of the container.

17. The apparatus according to claim 1, wherein the interior of container is substantially cylindrical comprising a level basal surface, and comprising a side wall extending perpendicularly from the basal surface.

18. The apparatus according to claim 1, wherein the blade is arranged in the quarter of the container nearest a basal surface, at a distance of from 10 mm to 400 mm from the basal surface.

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